

## Full Length Research Paper

# *Ips typographus* (L.) and *Thanasimus formicarius* (L.) populations influenced by aspect and slope position in Artvin-Hatila valley national park, Turkey

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This study investigated the effects of aspect (north and south) and slope position (top slope: 1100 - 1700 m and bottom slope: 1700 - 2200 m) on *Ips typographus* (L.) and its major predator *Thanasimus formicarius* (L.) populations and body length and weight of the pest *I. typographus* (L.) in oriental spruce [*Picea orientalis* (L.) Link.], dominated stands in Artvin-Hatila Valley National Park, Turkey for two years (2006-2007). A total of 120 pheromone traps were used to assess the population levels of both insect species. The results of the study were as follows: 1.) *I. typographus* (L.) population on each aspect was significantly higher at the top slope stands than the other sites whereas *T. formicarius* (L.) population was higher at the bottom slope stands on the north-facing site. 2.) There was no correlation between the number of *T. formicarius* (L.) and *I. typographus* (L.) caught by pheromone traps. 3.) Body length and weight of *I. typographus* (L.) were significantly higher on south aspect and at the top slope on each aspect.

**Key words:** *Ips typographus* (L.), *Thanasimus formicarius* (L.), pheromone, Hatila Valley, Turkey, aspect, altitude.

## INTRODUCTION

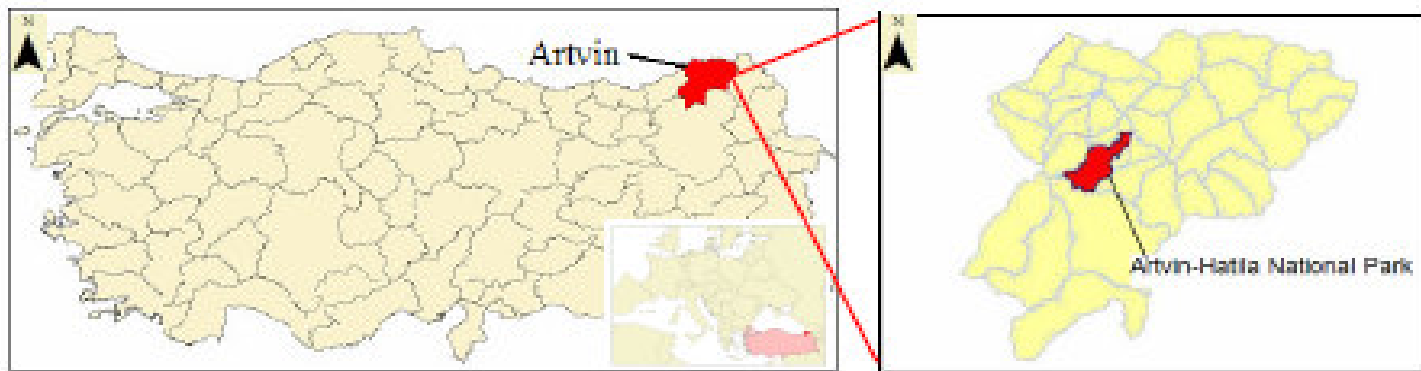
The spruce bark beetle [*Ips typographus* (L.) (Col., Scolytidae)] is one of the most destructive bark beetle species attacking mostly oriental spruce [*Picea orientalis* (L.) Link] forests in Turkey. The pest was first recorded in Artvin Province (Turkey) in 1984 (Alkan, 1985). Since then, it has spread to all over the oriental spruce forests in Eastern Blacksea region of Turkey (Akkuzu and Güner, 2008). In this region, one of the most destructive damage caused by *I. typographus* (L.) has occurred in Artvin-Hatila National Park over the last decade. Today, it has been estimated that the bark beetle *I. typographus* (L.) has infested and damaged 15,000 ha spruce forest in Hatila National Park (Sunar Erbek et al., 2005).

In latent conditions, the bark beetle *I. typographus* (L.) preferably attacks stressed and wind-thrown trees, which have a lower level of resistance (Chararas, 1962; Lindelöw et al., 1991). Epidemic population developments are only observed following storms and large scale wind-felled spruce damage providing abundant breeding

material (Warzee et al., 2006). During outbreaks, high population levels make it able to kill healthy trees that have a higher critical threshold of attack density (Mulock and Christiansen, 1986). A detailed description of the ecology and biology of the species can be found in Christiansen and Bakke (1988) and Wermelinger (2004).

The ant beetle [*Thanasimus formicarius* (L.) (Col., Cleridae)], one of the most common predators of *I. typographus* (L.) in Turkey, feeds on 27 bark-beetle species belonging to 15 genera (*Dendroctonus*, *Dryocoetes*, *Hylastes*, *Hylesinus*, *Hylurgops*, *Hylurgus*, *Ips*, *Leperesinus*, *Orthotomicus*, *Pityogenes*, *Pityokteines*, *Polygraphus*, *Scolytus*, *Tomicus* and *Trypodendron*) (Gauss, 1954; Mills, 1983; Tommeras, 1988). *T. formicarius* (L.) exerts a significant impact on the population dynamics of *I. typographus* (L.) (Mills, 1985; 1986; Weslien, 1992; Weslien and Regnander, 1992) because of its high fecundity [106 – 162 eggs/female (Dippel et al., 1997; Weslien and Regnander, 1992)] and its high voracity at the adult stage [0.86 to 2 – 3 adult *I. typographus* (L.) per day (Faccoli and Stergulf, 2004; Weslien and Regnander, 1992)] as well as at the larval stage (44 – 57 prey larvae during the whole larval life: (Dippel et al., 1997; Hérard and Mercadier, 1996; Mills,

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**Figure 1.** Location of the Artvin-Hatila National Park in Turkey.

1985)]. Adults of *T. formicarius* (L.) live 4 to 10 months (Gauss, 1954) and respond to the pheromones of *I. typographus* (L.) (Bakke and Kvamme, 1981).

A number of studies have shown that climate and topographic factors influence the population dynamics of *I. typographus* (L.) and *T. formicarius* (L.) (Funke and Petershagen, 1994; Lobinger, 1994; Lobinger and Skatulla, 1996; Lexer, 1997; Jakus, 1998; Grodzki, 2004; Rouault et al., 2006). In local areas, it is well known that topographic conditions such as slope and aspect can have a strong influence on microclimatic factors (especially temperature and rainfall). In Northeast Turkey, in which this present study was carried out, aspect and slope positions are very important topographical factors influencing local site microclimate, soil chemistry, litter quality, and litter decomposition rates (Sariyildiz et al., 2005; Sariyildiz et al., 2008). Over the last decade, *I. typographus* (L.) attack rates on pure oriental spruce in the Artvin-Hatila Valley National Park also seem to be influenced by topographical landforms (aspects and slope positions) (Sariyildiz et al., 2008).

To our knowledge, there have been no detailed studies on the effects of topographic conditions on the spruce bark beetle *I. typographus* (L.) and its predator *T. formicarius* (L.) populations. The objectives of the present study were to investigate the effects of aspects and slope positions on *I. typographus* (L.) and *T. formicarius* (L.) populations, and the body length and weight of *I. typographus* (L.).

## MATERIALS AND METHODS

### Study area

The study was conducted during the summer of 2006 and 2007 in Artvin-Hatila National Park (41° 51' N, 41° 06' E), a protected state park located in Eastern Blacksea Region of Turkey (Figure 1). Within the study area, there are mixed stands made up of spruce, hornbeam, fir, beech and oak, but over the altitude of 1700 m up to 2100 m forest formation type are almost pure oriental spruce trees, and has been under attack by *I. typographus* (L.) over the last two

decades (Table 1). The soil type in the study area was mainly a well-drained inceptisol soil with the texture of sandy loam.

Climate is generally characterized by cold winters and semi-arid summers (1948 – 2000 meteorological data from Artvin Meteorology Station) (Sariyildiz et al., 2005). Average monthly temperature ranged from 32°C in August to -2.5°C in January in the year 1948 - 2000. The mean annual precipitation in higher slopes reached over 1100 mm and the lowest temperature was recorded as -6.1°C in January 2000 (Damar meteorology station at 1550 m) (Sariyildiz et al., 2005).

### Field experiment

Four oriental spruce study plots were selected from north and south aspects at two zones of altitude [1. 1100 - 1700 m (bottom slope), 2. 1700 - 2200 m (top slope)]. A total of 120 multifunnel pheromone traps with commercial pheromone Pheroprax® were deployed in four study plots (30 traps for each). The most important attractants for *T. formicarius* (L.) are the volatiles produced by *I. typographus* (L.) (Hansen, 1983). *T. formicarius* (L.) is strongly attracted to ipsdienol and ipsenol, less to cis-verbenol and not at all to methylbutenol (Bakke and Kvamme, 1981). Furthermore, *T. formicarius* (L.) has been shown to exploit pheromonal products of several bark beetles besides *I. typographus* (L.) (Tommeras, 1988; Zümr, 1988). Thus, commercial pheromone Pheroprax® was used to assess the distribution of *T. formicarius* (L.) in the study area. All traps were fastened to wooden sticks at a height of 1.5 m above ground. The quantification of captured insects took place every 7 - 10 days by counting insects, or by measuring volume of the insects if the catch were greater than 500 insects per trap.

In each study sites, a total of 100 spruce tree (stem >8 cm diameter at breast height, 1.3 m above ground level) was measured for height, diameter, age and double bark thickness. Tree age was determined by counting each annual growth ring in the trunk of the tree. Tree heights, double bark thickness and diameters at the breast height were measured with a Blume-Leiss altimeter, a bark gauge and a diameter tape, respectively. After that, mean stand age, height, double bark thickness and tree diameter were calculated. The location and stand characteristics of the studied sites are shown in Table 2.

A total of 720 adult *I. typographus* (L.) (180 beetles in each site) were collected from bark beetle-infested spruce trees for the purpose of measuring body length and weight of the beetles. Each oven-dried (60°C for 24 h) *I. typographus* (L.) was weighed and its length measured by a trinocular stereozoom microscope and a computer image analyzer program (ImPA®).

**Table 1.** Primary features of the study sites in Artvin-Hatila National Park.

Feature	North		South	
	Top Slope	Bottom Slope	Top Slope	Bottom Slope
Slope angle (%)	55	65	60	65
Slope (m)	1700 - 2200	1100 - 1700	1700 - 2200	1100 - 1700
Mineral soil texture	Sand	Sandy loam	Sandy loam	Sandy loam
Canopy cover (%)	61.7	78.4	57.3	75.4
Stand mixture	Spruce (80 - 95 %), others (fir, beach) (5 - 20%)	Spruce (50 - 80%), others (hornbeam, fir, beach, oak) (20 - 50%)	Spruce (80 - 95%), others (fir, beach) (5 - 20%)	Spruce (50 - 80%), others (hornbeam, fir, beach, oak) (20 - 50%)

**Table 2.** Location and stand characteristics of oriental spruce from two slope positions on north and south aspect.

Characteristic	North		South	
	Top Slope	Bottom Slope	Top Slope	Bottom Slope
Age (year) $\pm$ SE	109.02 $\pm$ 1.47b	101.88 $\pm$ 1.04c	123.04 $\pm$ 1.29a	103.62 $\pm$ 1.21c
Height (m) $\pm$ SE	25.54 $\pm$ 0.38b	21.78 $\pm$ 0.37c	29.42 $\pm$ 0.32a	21.14 $\pm$ 0.36c
Double bark thickness (cm) $\pm$ SE	2.66 $\pm$ 0.60b	2.29 $\pm$ 0.57c	3.09 $\pm$ 0.52a	2.24 $\pm$ 0.37c
Tree diameter (cm) $\pm$ SE	40.66 $\pm$ 1.24b	27.62 $\pm$ 0.72c	47.80 $\pm$ 1.00a	24.22 $\pm$ 0.70d

Different letters after the means indicate a significant difference between the means (Least Significant Difference (LSD) Test,  $p \leq 0.05$ )

### Statistical methods

A two-way MANOVA analysis was employed to examine the effects of both slope and aspect on *I. typographus* (L.) and *T. formicarius* (L.) densities and on body length and weight of *I. typographus* (L.) in the study area. After that, a separate two-way ANOVA was subsequently carried out for each species. When significant differences occurred in these two-way ANOVAs, LSD test with  $p < 0.05$  was used for mean separation after a significant factor effect was confirmed by one-way ANOVAs. The Pearson Correlation test was used to evaluate the relationship between the number of *T. formicarius* (L.) and *I. typographus* (L.) captured by pheromone traps. All statistical analyses were performed with the significance level of  $\alpha = 0.05$  using SPSS® 15.0 for Windows® software.

### RESULTS

There is a significant effect of slope ( $p < 0.001$ ), aspect ( $p < 0.001$ ) and slope-aspect interaction ( $p < 0.001$ ) on *I. typographus* (L.) and *T. formicarius* (L.) densities (Two-way MANOVA,  $\alpha = 0.05$ ) (Table 3). Separate two-way ANOVAs showed that slope ( $p < 0.001$ ), aspect ( $p < 0.001$ ) and slope-aspect interactions ( $p < 0.001$ ) were all significant (Table 3). Both slope and aspect affected the density of *I. typographus* (L.) and *T. formicarius* (L.) in the region.

Subsequent one-way ANOVAs revealed significant differences in captured species by pheromone traps among the four study plots (treatments) of *I. typographus* (L.) ( $F_{3,956} = 34.798$ ) and *T. formicarius* (L.) ( $F_{3,956} = 26.117$ ). LSD test with  $p < 0.05$  was showed that number of *I. typographus* (L.) captured by pheromone traps was significantly higher at top slope positions on the south

**Table 3.** Results of two-way MANOVA and two-way ANOVAs applied to the effects of the slope and aspect on the number of *I. typographus* (L.) and *T. formicarius* (L.).

	df	F	p
<b>Two-way MANOVA</b>			
Slope	2	26.167	<0.001
Aspect	2	32.604	<0.001
Slope x Aspect	2	32.214	<0.001
<b>Two-way ANOVA</b>			
Slope (I) *	1	37.294	<0.001
Aspect (I)	1	31.066	<0.001
Slope x aspect (I)	1	36.036	<0.001
Error (I)	956		
Slope (T) **	1	15.665	<0.001
Aspect (T)	1	34.989	<0.001
Slope x aspect (T)	1	27.697	<0.001
Error (T)	956		

\* (I): *I. typographus* (L.).

\*\* (T): *T. formicarius* (L.).

aspect than the other sites (Table 4).

Mean number of the pest captured was similar at bottom slope positions on both south and north-facing site and top slope positions on north-facing site. It means there were no significant differences among these sites (Table 4).

On the other hand, LSD test revealed that number of *T. formicarius* (L.) captured by pheromone traps was significantly higher at bottom slope on north-facing sites

**Table 4.** Mean number of *I. typographus* (L.) and *T. formicarius* (L.) captured by pheromone traps.

Slope (m)	Aspect	Traps*	Mean number of <i>I. typographus</i> ±SE	Mean number of <i>T. formicarius</i> ±SE
Bottom slope	South	240	4.5625±0.4614b	0.0917±0.0229b
	North	240	18.5792±1.7871b	1.1625±0.1820a
Top slope	South	240	399.9375±65.2432a	0.2167±0.0393b
	North	240	21.9708±1.9438b	0.2792±0.0388b

Different letters after the means indicate a significant difference between the means (LSD test,  $p < 0.05$ ). \* Number of traps controlled throughout the study period.

**Table 5.** Pearson correlation coefficients showing the relationships between the number of *I. typographus* (L.) and *T. formicarius* (L.) captured by pheromone traps.

Species		<i>I. typographus</i>	<i>T. formicarius</i>
<i>I. typographus</i>	Pearson correlation	1	-0.035
	Sig. (2-tailed)		0.275
	N	960	960
<i>T. formicarius</i>	Pearson correlation	-0.035	1
	Sig. (2-tailed)	0.275	

**Table 6.** Results of two-way MANOVA and two-way ANOVAs applied to the effects of the slope and aspect on body weight and length of *I. typographus* (L.).

	df	F	p
<b>Two-way MANOVA</b>			
Slope	2	5.157	0.006
Aspect	2	7.240	0.001
Slope x Aspect	2	0.026	0.975
<b>Two-way ANOVA</b>			
Slope (L) *	1	8.314	0.004
Aspect (L)	1	9.211	0.003
Error (L)	716		
Slope (W) **	1	9.441	0.002
Aspect (W)	1	14.346	<0.001
Error (W)	716		

\* (L): body length of *I. typographus* (L.).

\*\* (W): body weight of *I. typographus* (L.).

than the other sites. There were no significant differences among the other sites (Table 4).

There was an insignificant correlation between the number of *T. formicarius* (L.) and *I. typographus* (L.) captured by pheromone traps (Pearson correlation:  $r = -0.035$ ,  $N = 960$ ,  $P = 0.275$ ) (Table 5).

Both slope ( $p = 0.006$ ) and aspect ( $p = 0.001$ ) significantly affected the body length and weight of *I. typographus* (L.). No significant slope x aspect interaction ( $p = 0.975$ ) effect was however revealed by two-way

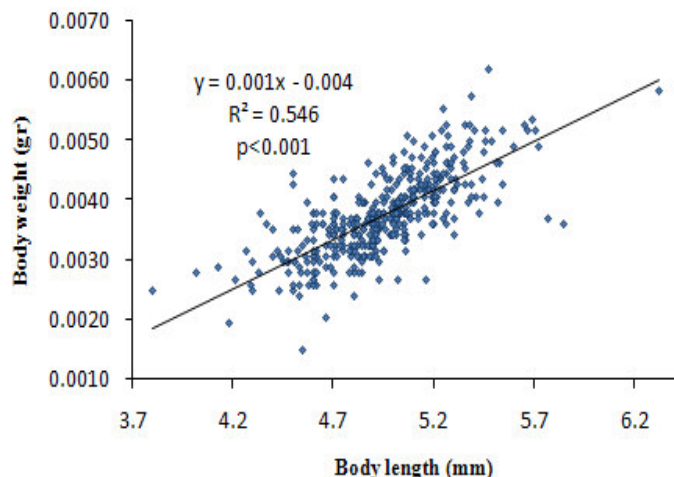
**Table 7.** Summary of measurements of body length and weight of *I. typographus* (L.) by slope and aspect.

Parameter	Body length		Body weight	
	Mean	SD	Mean	SD
<b>Slope</b>				
Bottom	4.9073	0.2843	0.0040	0.0007
Top	4.9921	0.3112	0.0042	0.0008
<b>Aspect</b>				
South	4.9943	0.2811	0.0042	0.0007
North	4.9051	0.3135	0.0039	0.0007

MANOVA ( $\alpha = 0.05$ ) (Table 6). The length and weight of the beetles were significantly bigger at top slope positions and south aspects than the other sites (Tables 6 and 7). Significant positive linear correlations were found between body length and weight of the beetles (Figure 2).

## DISCUSSION

*I. typographus* (L.) was trapped in higher numbers at top slope positions on south-facing site than the other sites (Table 3 and 4). This is in agreement with the results by Grodzki (2004) on *I. typographus* (L.). Many studies have also shown that south-exposed and sunlit trees are preferably attacked, especially after abrupt increases in solar radiation levels (Lobinger and Skatulla, 1996; Jakus, 1998). Most studies have noted that there is a strong relationship between the number of insects per trap and the number of trees attacked by *I. typographus*



**Figure 2.** Relationship between body length and weight for *I. typographus* (L.).

(L.) (Faccoli and Stergulc, 2004). Weslien et al. (1989) reported that the risk of trees being killed by *I. typographus* (L.) increases with increasing beetle population density.

In the study area, stands at bottom slope positions are made up of diverse tree composition (that is, hornbeam, fir, beach and oak) and ground vegetation. Stands at upper elevations are however formed by almost pure spruce trees. Jactel et al. (2005) reported that forests with highly diverse tree composition, age structure, and ground vegetation have a different tree physiology and are more resistant to windthrow and bark beetle attack.

Mean tree age, height, diameter, and double bark thickness at top slope positions on south-facing site were significantly higher than the other sites (Table 2). As forests age they become more vulnerable to agents of disturbance, such as high winds, fire, fungi, and bark beetles (Christiansen et al., 1987). Higher proportions of spruce trees in a stand were found to enhance bark beetle attack as were trees older than 70 years, with trees over 100 years being most susceptible (Becker and Schröter, 2000).

Bark anatomy and the physiological condition of a potential host tree are crucial for the success of a bark beetle attack (Wermelinger, 2004). Spruces with thick bark and dense resin ducts seem to be more efficient in repelling boring attempts than thin-barked, low resin trees (Nihoul and Nef, 1992; Baier, 1996). Trees in mixed stands had a higher primary resin flow than those in pure spruce stands (Baier et al., 2002).

This study has shown that *T. formicarius* (L.) population level does not directly depend on the *I. typographus* (L.) population level (Tables 4 and 5). Although the number of *I. typographus* (L.) caught by pheromone traps was higher at top slope on south-facing sites than the other sites, *T. formicarius* (L.) was higher at bottom slope on north-facing sites (Table 4). The result was somewhat

surprising since we expected to find a significant correlation between the number of *I. typographus* (L.) and *T. formicarius* (L.) caught by pheromone traps. This result could depend on following reasons:

1) As Gauss (1954), Mills (1983) and Tommeras (1988) indicated that *T. formicarius* (L.) feeds not only on *I. typographus* (L.), but also 27 bark beetle species. Possibly, the predator feeds on some other host species at bottom slope on north-facing sites. 2) The spruce bark beetle has high dispersal abilities and can thus escape the local mortality agents (Wermelinger, 2004). At new potential infestation spots the local density of antagonists may be still low, which allows the bark beetles to build up new populations successfully (Wermelinger, 2004).

3) In the study area, bottom slopes are made up of mixed stands of spruce, hornbeam, fir, beach, and oak. In mixed forests, in comparison to monocultures, the abundance of predators and parasitism is higher (Jäkel and Roth, 2004).

The length and weight of *I. typographus* (L.) were significantly higher at top slope positions and south aspects (Tables 6 and 7). As Grodzki (2004) indicated that these stands probably offered more favorable breeding conditions for bark beetles due to the reduced resistance of individual trees, which could have resulted in the increased average length of *I. typographus* (L.) adults. In stands that sustained lower levels of mortality (that is, representing higher resistance), the beetles were smaller (Grodzki, 2004).

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## REFERENCES

- Akkuzu E, Guner S (2008). Defoliation levels of oriental spruce by *Ips typographus* (L.) in relation to elevation and exposure. J. Environ. Biol. 29(2): 223-226.
- Alkan S (1985). Savsat Isletmesi Ormanlarinda *Dendroctonus micans* Kug. (Dev soymuk bocegi). Orman Muhendisligi Dergisi. 22(1): 59-62.
- Baier P (1996). Defence reactions of Norway spruce (*Picea abies* Karst) to controlled attacks of *Ips typographus* (L.) (Col Scolytidae) in relation to tree parameters. J. Appl. Entomol. 120: 587-593.
- Baier P, Führer E, Kirisits T, Rosner S (2002). Defence reactions of Norway spruce against bark beetles and the associated fungus *Ceratomyces polonica* in secondary pure and mixed species stands. For. Ecol. Manag. 159: 73-86.
- Bakke A, Kvamme T (1981). Kairomone response in *Thanosimus* predators to pheromone components of *Ips typographus*. J. Chem. Ecol. 7(2): 305-312.
- Becker T, Schröter H (2000). Ausbreitung von rindenbrütenden Borkenkäfern nach Sturmschäden. Allg. Forstztg. 55: 280-282.



- Chararas C (1962). Scolytides des conifères. P. Lechevalier, Paris, France.
- Christiansen E, Bakke A (1988). The spruce bark beetle of Eurasia. In: Berryman AA (Eds) Dynamics of forest insect populations. Plenum Publishing Corporation, New York, pp. 479-503.
- Christiansen E, Waring RH, Berryman AA (1987). Resistance of conifers to bark beetle attack: Searching for general relationships. For. Ecol. Manag. 22: 89-106.
- Dippel C, Heidger C, Nicolai V, Simon M (1997). The influence of four different predators on bark beetles in European forest ecosystems (Coleoptera: Scolytidae). Ent. Gen. 21: 161-175.
- Gauss R (1944-1951, 1954). Der ameisenbunkkäfer *Thanasimus formicarius* latr. als borkenkäferfeind. In: Wellenstein G (Eds) Die grosse Borkenkäferkalamität in Südwest-Deutschland, pp. 417-429.
- Grodzki W (2004). Some reactions of *Ips typographus* (L.) (Coleoptera: Scolytidae) to changing breeding conditions in a forest decline area in the Sudeten Mountains, Poland. J. Pest Sci. 77: 43-48.
- Faccoli M, Stergulic F (2004). *Ips typographus* (L.) pheromone trapping in south Alps: spring catches determine damage thresholds. J. Appl. Entomol. 128: 307-311.
- Funke W, Petershagen M (1994). Zur Flugaktivität von Borkenkäfern. Jahresber. Naturw. Ver. Wuppertal 47: 5-10.
- Hansen K (1983). Reception of bark beetle pheromone in the predaceous clerid beetle, *Thanasimus formicarius* (Coleoptera: Cleridae). J. Comp. Physiol. 150: 371-378.
- Hérard F, Mercadier G (1996). Natural enemies of *Tomicus piniperda* and *Ips acuminatus* (Col., Scolytidae) on *Pinus sylvestris* near Orléans, France: temporal occurrence and relative abundance, and notes on eight predatory species. Entomophaga. 41: 183-210.
- Jactel H, Brockerhoff E, Duelli P (2005). A test of the biodiversity-stability theory: Meta-analysis of tree species diversity effects on insect pest infestations, and re-examination of responsible factors. In: Scherer-Lorenzen M, Körner C, Schulze ED (Eds) Forest Diversity and Function. Ecological Studies, Springer-Verlag, Berlin. 176: 235-262.
- Jäkel A, Roth M (2004). Conversion of single-layered Scots pine monocultures into close-to-nature mixed hardwood forests: effects on parasitoid wasps as pest antagonists. Eur. J. Forest Res. 123: 203-212.
- Jakus R (1998). Types of bark beetle (Coleoptera: Scolytidae) infestation in spruce forest stands affected by air pollution, bark beetle outbreak and honey fungus (*Armillaria mellea*). Anz. Schäd. kd. Pflanzenschutz Umweltschutz. 71: 41-49.
- Lexer MJ (1997). Risikoanalyse und ableitung waldbaulicher massnahmen zur beeinflussung des borkenkäferisikos in fichtenbeständen. FBVA (Forstl. Bundesvers. Anst.). Berichte. 95: 79-89.
- Lindelöw A, Risberg B, Sjödin K (1991). Attraction during flight of scolytids and other bark- and wood-dwelling beetles to volatiles from fresh and stored spruce wood. Can. J. Forest Res. 22: 224-228.
- Lobinger G (1994). Die Lufttemperatur als limitierender faktor für die schwärmaktivität zweier rindenbrütender fichtenborkenkäferarten, *Ips typographus* L. und *Pityogenes chalcographus* L. (Col., Scolytidae). Anz. Schäd. kd. Pflanzenschutz Umweltschutz. 67: 14-17.
- Lobinger G, Skatulla U (1996). Untersuchungen zum Einfluss von Sonnenlicht auf das Schwärmverhalten von Borkenkäfern. Anz. Schäd. kd. Pflanzenschutz Umweltschutz 69: 183-185.
- Mills NJ (1983). The natural enemies of scolytids infesting conifer bark in Europe in relation to the biological control of *Dendroctonus* spp. in Canada. Biocontr. News Inform. 4(4): 305-328.
- Mills NJ (1985). Some observations on the role of predation in the natural regulation of *Ips typographus* populations. Z. Angew. Entomol. 99: 209-215.
- Mills NJ (1986). A preliminary analysis of the dynamics of within tree populations of *Ips typographus* (L.) (Col.: Scolytidae). J. Appl. Entomol. 102: 402-416.
- Mulock P, Christiansen E (1986). The threshold of successful attack by *Ips typographus* on *Picea abies*: a field experiment. For. Ecol. Manag. 14: 125-132.
- Nihoul P, Nef L (1992). Caractéristiques anatomiques de l'écorce de l'épicéa commun *Picea abies* Karst. et intensité des attaques d'*Ips typographus* L. (Col., Scolytidae). J. Appl. Entomol. 114: 26-31.
- Rouault G, Candau JN, Lieutier F, Nageleisen LM, Martin JC, Warzee N (2006). Effects of drought and heat on forest insect population in relation to the 2003 drought in Western Europe. Ann. For. Sci. 63: 613-624.
- Sariyildiz T, Akkuzu E, Kucuk M, Duman A, Aksu Y (2008). Effects of *I. typographus* (L.) damage on litter quality and decomposition rates of Oriental Spruce [*Picea orientalis* (L.) Link.] in Hatila Valley National Park, Turkey. Eur. J. For. Res. 127: 429-440.
- Sariyildiz T, Anderson JM, Kucuk M (2005). Effects of tree species and topography on soil chemistry, litter quality, and decomposition in Northeast Turkey. Soil Biol. Biochem. 37: 1695-1706.
- Sunar Erbek F, Olmez Z, Uca Avci D (2005). Artvin yoresinde ladin (*Picea orientalis* L. Link.) orman alanlarinda bocek zararilari nederiyle olusan tahribatin izlenmesinde uydu goruntulerinin kullanimi. Ladin Sempozyumu, Trabzon, 1: 222-232.
- Tommeras BA (1988). The clerid beetle *Thanasimus formicarius* is attracted to the pheromone of the ambrosia beetle *Trypodendron lineatum*. Experientia. 44: 536-537.
- Warzee N, Gilbert M, Gregoire JC (2006). Predator/prey ratios: a measure of bark-beetle population status influenced by stand composition in different French stands after the 1999 storms. Ann. For. Sci. 63: 301-308.
- Wermelinger B (2004). Ecology and management of the spruce bark beetle *Ips typographus* – a review of recent research. For. Ecol. Manag. 202: 67-82.
- Weslien J, Annala E, Bakke A, Bejer B, Eidmann HH, Narvestad K, Nikula A, Ravn HP (1989). Estimating risk for spruce bark beetle (*Ips typographus* (L.)) damage using pheromone-baited traps and trees. Scand. J. For. Res. 4: 87-98.
- Weslien J (1992). The arthropod complex associated with *Ips typographus* (L.) (Col., Scolytidae) species composition, phenology, and impact on bark beetle productivity. Entomol. Fenn. 3: 205-213.
- Weslien J, Regnander J (1992). The influence of natural enemies on brood production in *Ips typographus* (Col.: Scolytidae) with special reference to egg-laying and predation by *Thanasimus formicarius* (Col.: Cleridae). Entomophaga. 37: 333-342.
- Zumr V (1988). The effectiveness of the aggregation pheromone chalcoprax in the control of spruce wood engraver *Pityogenes chalcographus* L. (Coleoptera, Scolytidae). Lesnictvi. 34: 489-498.